TEST F1.2

ELECTROSTATIC DISCHARGE (ESD)

F1.1 PURPOSE

This is a laboratory safety and reliability test simulating possible handling, ground & aircraft transportation and in-flight conditions. The fuze must withstand high-potential electrostatic discharge (lightning environment is excluded).

F1.2 DESCRIPTION

F1.2.1 General. Bare and packaged unarmed fuzes are subjected to discharges of electrostatic energy at selected exterior points. Each fuze shall be subjected to four tests. The first test, personnel-borne ESD, simulates the maximum electrostatic discharge from the human body and is performed at two different test conditions representative of such discharges. The final two tests, helicopter-borne ESD and High Voltage Corona, are performed on packaged and bare fuzes, by simulating the maximum expected electrostatic discharge during vertical replenishment by hovering aircraft and in-flight conditions.

F1.2.1.1 Personnel-borne ESD (bare). This test shall be conducted on bare fuzes to evaluate their safety and operability.

F1.2.1.2 Helicopter-borne ESD (packaged). This test shall be conducted on fuzes in their standard packaged configuration (unit or bulk packaging and shipping container) to evaluate their safety and operability.

F1.2.1.3 Helicopter-borne ESD (bare). This test shall be conducted on bare fuzes to evaluate their safety only.

F1.2.1.4 High Voltage, Corona (In-Flight). This test shall be conducted on fuzed projectiles to evaluate their safety and operability.

F1.2.2 Selection of test points. Selection of test points for the fuze or container shall be based on the item's particular points deemed by engineering judgment to be the most susceptible to direct penetration or to excitation of the structure and subsequent internal distribution of the electromagnetic energy from the discharge.

F1.2.2.1 Bare fuzes. Fuzes shall be tested in all expected electrostatically-significant handling configurations, both with and without caps, covers and protective devices, to insure evaluation of realistic worst-case conditions. When selecting test points on a fuze, special attention and consideration shall be given to connectors, pins, apertures, slots, joints and other discontinuities that may transfer energy by electric (E-field) or magnetic (H-field) coupling.

F1.2.2.2 Packaged fuzes. Fuzes shall be in their shipping containers in their normal shipping configurations (for example, intact solder-seal lids or metal foil tapes or wraps). When selecting test points on a container, special attention shall be given to joints and other discontinuities that may transfer energy by electric (E-field) or magnetic (H-field) coupling.

F1.2.3 Environmental conditions. The test shall be conducted on fuzes at an ambient temperature of +23ºC±10ºC (+73ºF±18ºF). Relative humidity of the ambient atmosphere shall be no greater than 50%. The fuze shall be preconditioned at +23ºC±10ºC (+73ºF±18ºF), relative humidity no greater than 50% for no less than 24 hours prior to this test.

F1.2.4 Fuze configuration. The fuzes shall be completely assembled except that lead and booster charges, if considered to be insensitive or inaccessible to electrostatic discharge, may be omitted to facilitate testing. If any explosive elements are removed, care should be exercised to preserve electromagnetic equivalency of the resulting configuration.

F1.2.5 Applicable publications. All standards, specifications, drawings, procedures and manuals which form a part of this test are listed in Section 2 of the introduction to this standard. Special attention is directed to MIL-HDBK-1512, MIL-STD-322 and MIL-I-23659 which have specific applications.

F1.2.6 Test documentation. Test plans, performance records, equipment, conditions, results, and analysis shall be documented in accordance with 4.8 of the general requirements to this standard. The test plan shall also specify:

a. The number and configuration of fuzes for each discharge; the location of discharge points; the number of times each fuze may be subjected to discharge; the type of electrode to be used (see F1.4.4); the discharge gap or description of the mechanism utilized to move the electrode toward the test item (see F1.4.5); and the test sequence (see F1.5.2).

b. The performance requirements, pre-test data (for example, electroexplosive device (EED) bridge resistance and thermal time constants) and parameters for determining proper evaluation of the fuze during and after test, including how cumulative damage, if any is to be assessed.

F1.3. CRITERIA FOR PASSING TEST

F1.3.1 Fuze condition after personnel-borne ESD (bare) and helicopter-borne ESD (packaged) tests. At the completion of these tests, the fuze shall be safe for transportation, storage, handling and use, as well as operable in accordance with 4.6.2.1a and 4.6.2.2 of the general requirements to this standard.

F1.3.2 Fuze condition after helicopter-borne ESD (bare) test. At the completion of this test, the fuze shall be safe for transportation, storage, handling and use in accordance with 4.6.2.2a of the general requirements to this standard. The fuze does not have to be operable.

F1.3.3 Fuze condition after High Voltage, Corona (In-Flight) test. At the completion of this test, the fuze shall be safe for transportation, storage, handling and use in accordance with 4.6.2.2a of the general requirements to this standard. The fuze should remain operable after exposure.

F1.3.4 Decision basis. Breakdown, inspection, other appropriate tests and engineering judgment shall form the basis for the decision that fuzes have passed or failed the test.

F1.4. EQUIPMENT

F1.4.1 Test apparatus. The functional electrical schematic for the test apparatus is shown in Figures F1-1, 6 and 7.

F1.4.2 Energy delivery capability. The energy delivery capability of the test apparatus shall be verified and recorded on a daily basis. If a salient is used on the test item, it shall be considered part of the discharge circuit.

F1.4.2.1 Personnel-borne ESD test. The energy delivered to each of the calibration test loads given in Table F1-1 shall be between 0.18% and 0.22% (when using a 500 ohm series resistance) or between 0.018% and 0.022% (when using a 5000 ohm series resistance) of the energy stored on capacitor C. Section F1.7.3.2.1 provides a description of the threat to fuzes or their subsystems caused by an electrostatic discharge from a human body. Section F1.7.4 provides a description of the required instrumentation and a procedure for measuring the energy delivered by the test apparatus used to simulate the threat. Calibration test waveforms should fall within the bounds specified in Figures F1-2 through F1-5, as applicable.

F1.4.2.2 Helicopter-borne ESD test. The energy delivered to the calibration test load given in Table F1-1 shall be between 80% and 100% of the energy stored on capacitor C.

F1.4.2.3 High Voltage, Corona test. The voltage level delivered to the fuze shall be verified using a high input impedance volt meter and a high voltage probe that can handle voltage levels up to +/- 150,000 volts.

F1.4.3 Circuit component characteristics.

F1.4.3.1 Power supply. The power supply shall provide both positive and negative test voltages with respect to ground.

F1.4.3.2 Isolation circuitry. Isolation circuitry I shall isolate the test item from the charging circuit during charging of capacitor C and shall isolate the power supply from the discharge circuit during discharge to the test item.

F1.4.3.3 Series resistance. The series resistance R shall be non-inductive. For the air replenishment test, R represents the allowable total discharge circuit resistance, excluding the test item (see F1.4.1).

F1.4.3.4 Capacitor. Capacitor C shall be chosen to minimize inductance and leakage.

F1.4.3.5 Storage Scope. To properly record test waveforms, a oscilloscope is required having at least a DC to 100 MHz frequency response, 50-ohm input impedance, and both storage and hard-copy capability.

F1.4.3.6 Test parameters. The voltage, capacitance, resistance, discharge circuit inductance, and calibration test load for each test procedure, including the inductance of the capacitor and wiring to the probes shall be in accordance with the values in Table F1-1. Inductance shall be measured at a nominal 1 kHz frequency.

F1.4.4 Electrode characteristics. The test electrode shall be metal and have a size and shape that minimize corona. The electrode surface shall be maintained smooth, clean and shiny to insure high electrical conductivity and uniformity of discharge.

F1.4.5 Electrode control. A mechanism shall be provided to cause the test electrode either to discharge to the test item through a previously specified fixed gap (see F1.2.6a) or to move toward the test item at the speed at which it was calibrated. The electrode may be snubbed to prevent hitting the test item. Where it is desired to insure that the discharge is directed to a particular point on the test item or to assure contact by the electrode without mechanical shock, an electrically conductive salient may be attached to the test item. In this case, it shall be established that the salient can withstand the discharge arc and that the integument of the test item with salient omitted can also withstand a direct discharge arc. The salient shall be included in energy delivery calibration tests (see F1.4.2).

F1.4.6 Safety considerations. Proper safety interlocks, switches, grounds and procedures shall be used to protect test personnel from electrical and explosive hazards. A grounding rod with insulated handle (or equivalent) shall be provided to short circuit the test electrode to test-circuit ground while test personnel are setting up for the next discharge.

F1.5. PROCEDURE

F1.5.1 Test. Perform the Personnel ESD, Helicopter ESD discharge tests, and HV Corona tests in accordance with the following test plan. Test details, for example, configurations, order of trials, inspection and number of trials, shall be at the discretion of the test designer and shall be documented in the test plan.

F1.5.2 Test sequence. Items shall be tested for Personnel ESD and Helicopter ESD as follows:

a. The test item shall be positioned such that the test electrode can discharge to the first designated test point on the item.

b. Capacitor C shall be charged to the chosen voltage and polarity. After C is fully charged and has been isolated from the power supply, the test electrode is allowed to discharge to the test point.

c. The capacitor discharge energy shall be applied sequentially to each of the designated test points. The capacitor shall be fully recharged for each point.

d. The test sequence shall be stopped if the test item at any time gives an indication of failure to pass the test, or at the discretion of the test activity. After removal of residual electrical energy, the fuze shall be inspected for compliance with F1.3. Otherwise, sequential application of capacitor discharge energy to all selected test item points shall be continued.

e. The above sequence shall be repeated with opposite polarity voltage.

f. Steps a through e shall be performed for the remaining test items.

F1.5.3 Test sequence. Items shall be tested for High Voltage, Corona as follows:

a. The use of high explosives shall be minimized. Heat indicators or electronic instrumentation may be used in lieu of actual explosive components. If electronic instrumentation is used, it must fit inside the metal projectile body during the test.

b. Install the test fuze into the projectile as shown in Figure F1-7. This test can be done instrumented, with live squibs or heat indicators (custom made squib that instead of detonating, they change color). Fiber optic lines, instead of wires, must be used during instrumentation to prevent the high voltage from coupling to the wires.

c. For safety, test personnel will leave the test area or allow sufficient separation between themselves and the device under test. Personal protection equipment shall be used, as necessary.

d. In the fuze's un-powered and S&A out of line configuration, slowly, charge up the fuzed projectile to +120 kV. Note: Wind tunnel tests on fuzed 155mm projectiles have shown that a surface voltage of +/-75,000 volts can be generated on the surface of composite fuzes. For larger projectiles, this level could be higher as indicated by HESD. The value of 120,000 volts was used because most commercial available high voltage power supplies can meet this requirement.

e. Perform a test discharge between the grounding rod and the projectile. Observe the distance before a direct spark discharge occurs. Move the grounding rod near the grounding platform. In a spiral motion, move the grounding rod towards the fuze, while remaining sufficiently away from the fuze to avoid a direct spark discharge to the fuze. Listen for a sizzling sound of the Corona. Continue to bring the grounding rod closer to the projectile until there is a direct spark discharge to the projectile. Observe the Corona discharge along side the body of the projectile as shown in Figure F1-7.

f. Measure or observe (i.e loud sound or smoke indication) whether the squib has fired.

g. The ground rod shall be used to stress out the fuze. This simulates Corona discharge to the air during in-flight.

h. All results such as HVC voltage level, polarity, squib initiation (instrumented or by go/no-method) and any malfunction of the test fuze shall be recorded.

i. The test sequence shall be stopped if the test item at any time gives an indication of failure to pass the test, or at the discretion of the test activity. After removal of residual electrical energy, the fuze shall be inspected for proper operation. The damaged fuze shall be removed for failure analysis.

j. Steps (a) to (g) shall be repeated, but instead charge the fuzed projectile to –120 kV.

k. Repeat steps (a) through (h) shall be performed, but this time the S&A will be mechanically armed or in-line.

l. Repeat steps (a) through (g) shall be performed, but this time the S&A will be in-line and the Fuze will be powered and the safe separation condition will be simulated.

Note: Steps (k) and (l) represent the operational and arming steps the fuze would go through after leaving the gun. In addition, these steps would help the test agency to determine whether the squib fired or the fire control electronics initiated a firing command due to the HVC environment.

F1.5.4 Number of test sequences. A minimum of 22 test sequences shall be conducted when testing to the personnel-borne ESD threat in order to demonstrate 90% reliability with 90% confidence. This minimum number of sequences may be reduced to 10 (80% reliability, 85% confidence) when testing to the helicopter-borne ESD threat. This minimum number of sequences may also be reduced to

10 (80% reliability, 85% confidence) when testing for High Voltage, Corona requirements. For the purposes of this standard, a test sequence is defined as a series of discharges to the equipment-under-test at the test points identified in the pre-test assessment. Subsequent sequences may be conducted by using different items/munitions or on the same item/munition with a different set of EED's and electronic/electrical subsystems. The confidence level and reliability of test data versus the number of test sequences shall be considered when determining the number of test sequences.

F1.5.5 Compliance. Analyze the test results and determine whether or not the test article meets the pass/fail criteria it F1.3.

F1.6. ALTERNATE AND OPTIONAL TESTS

F1.6.1 Information testing. Testing at intermediate voltages between zero and 300 kilovolts should also be conducted to identify voltage breakdown paths which may not be observed at the voltages given in Table F1-1 and which may have an adverse effect on the test item. Parameters that should be considered for additional tests are provided in Table F1-2.

F1.6.2 Test to determine response of an armed fuze to electrostatic discharge. Fuze development testing or operational conditions may require that an armed fuze be handled. For these cases, it is recommended that the human body discharge test be conducted on armed fuzes to establish if they are sensitive to electrostatic discharges up to 25 kilovolts. The results of this test will also be helpful in establishing procedures for disposing of the fuze or rendering it safe by Explosive Ordnance Disposal personnel. In order to maximize safety to test personnel, the explosive train shall use the least amount of explosive material (i.e do not test with secondary explosives, leads or boosters, if possible). An analysis shall be made by the developer and test personnel to determine the need for explosives beyond electric detonator, piston actuator or other active primary explosive train components.

F1.6.3 Over test to determine response of an armed fuze to direct spark discharge. In the fuze's un-powered and S&A in-line configuration, slowly, charge p the fuzed projectile to +120 kV. Perform a test discharge between the grounding rod and the projectile. Observe the distance before a direct spark discharge occurs. Move the grounding rod near the grounding platform. In a spiral motion, move the grounding rod towards the fuze while remaining sufficiently away from the fuze to avoid a direct spark discharge to the fuze. Listen for a sizzling sound of the Corona discharge. Continue to bring the grounding rod closer to the fuze until there is a direct spark discharge to the fuze. Observe the Corona discharge along the side of the fuze. Repeat above procedures with – 120 kV.

F1.7. RELATED INFORMATION

F1.7.1 Relation to other environmental tests. Electrostatic discharge tests should be conducted either singly or as part of a sequence after other environmental tests have been completed on the fuze. It is suggested that fuzes be evaluated for susceptibility to electrostatic discharge after they have been attached to their associated weapons, if practical.

F1.7.2 Number of tests per fuze. The number of capacitor discharges to a particular fuze, bare or packaged, has not been specified and is at the discretion of the test activity. The determination of the permissible number of discharges should be based in part on whether cumulative damage should be counted in assessing whether the fuze meets the passing criteria of F1.3.

F1.7.3 Background.

F1.7.3.1 Nature of the problem. Many modern weapons contain EED's which are used to initiate a variety of functions such as rocket motor ignition, fuze and warhead detonation, power cartridge and fuze actuation, stores ejection, and many others. Many fuzes have electronic parts which include transistors, integrated circuits and various other solid-state devices related to timing, arming or firing functions. Through a normal logistic cycle, weapons undergo various phases of handling such as crating, uncrating, wrapping in protective plastics, removal from barrier bags, assembling, and transferring. These processes may result in the development of an electrostatic charge on the handler, transfer equipment, shipping containers, munitions or any other ungrounded object. The clothing worn by handling personnel, if made from a synthetic fiber, is especially hazardous.

F.1.7.3.1.1 Hovering aircraft used in vertical replenishment also develop a significant electrostatic charge. This may be discharged to an exposed lead of an EED or into an electronic circuit upon contact between the handler or associated equipment and the munition. If the charge is of sufficient magnitude, so that the energy dissipated exceeds the initiation threshold for the EED, an accidental initiation of the device will occur, resulting in either a serious hazard or dud weapon, depending on the function of the affected EED.

F.1.7.3.1.2 In a similar matter during In-Flight conditions, an armed fuze could develop a significant electrostatic surface charge due to the heavy use of composite materials. This may be discharged to an exposed lead of an EED or into an electronic circuit. If the surface charge is of sufficient magnitude, so that the energy dissipated exceeds the initiation threshold for the EED, an accidental initiation of the device will occur, resulting in either a serious hazard or dud weapon, depending on the function of the affected EED. If an electronic component is overloaded by excessive voltage, parametric or gross changes may occur that are detrimental to electronic functions such as signal processing, timing, arming and firing.

F1.7.3.2 Electrostatic environment.

F1.7.3.2.1 Personnel-borne. The physiological characteristics which affect the electrostatic hazard vary over a wide range. The degree of the hazard also depends on the type of clothing worn and the relative humidity of the ambient air. In most cases the upper-bound hazard may be represented by charging a low-loss, low-inductance 500-picofarad capacitor to 25 kilovolts and discharging it through a resistor with not more than 5 microhenries of total circuit inductance.

F1.7.3.2.2 Helicopter-borne. Helicopters and other hovering aircraft become electrostatically charged by ion emission from the engines and by the triboelectric charge separation on airfoils. Their characteristics vary over a wide range, but a typical upper bound may be represented by a 1000-picofarad capacitor charged to 300 kilovolts.

F1.7.3.2.3 High Voltage, Corona. During super sonic speeds, the surface of the Fuze gets striked by air particles causing the suface of the fuze to become electrostatically charged. The surface voltage characteristics vary over a wide range, but a typical the bigger the item the higher the voltage. However, based on wind tunnel testing, it was verified that a fuzed projectile is much smaller in size as compared to an aircraft. Therefore, exposing the fuzed projectile to less about +/- 120 kV is more than sufficient.

F1.7.4 Waveform characterization of the personnel-borne ESD threat. The heavy curves in Figures F1-2 and F1-3 represent typical 25 kilovolt pulses for the 500 ohm and 5000 ohm series resistances respectively. Risetimes are approximately 15 nanoseconds (10% to 90% of peak value). The range of waveforms for equipment used to simulate the personnel-borne ESD threat should fall within the bounds of the curves given in those figures. Figures F1-4 and F1-5 represent typical and boundaries for voltage waveforms as measured on a storage scope using the calibration circuit presented in Figure F1-6. The 1-ohm resistor should be coaxial in order to ensure the proper frequency response. Note that the test circuit in Figure F1-6 is commercially available. If possible, the probe should be touching the resistor contact when the discharge is triggered. This will produce the most consistent waveforms. Waveforms should be characterized before and after testing and included in the test report.

F1.7.5 Bibliography.

F1.7.5.1 Technical Report 62-72, *Helicopter Static-Electricity Measurements*, by James M. Seibert, US Army Transportation Research Center, June 1962.

F1.7.5.2. Technical Report 69-90, *Investigation of CH-54A Electrostatric Charging and of Active Electrostatic Discharge Capabilities*, by M. C. Becher, US Army Aviation Material Laboratories, January 1970.

F1.7.5.3 Technical Report TR-2207, *Evaluation of Dynasciences Model D-04E Active Electrostatic Discharge System Mounted on the CH-46A Helicopter*, by Charles L. Berkey, Naval Weapons Laboratory, September 1968.

F1.7.5.4 *Electromagnetic Criteria for US Army Missile Systems: EMC, EMR, EM, EMP, ESD, and Lightning*, by Charles D. Ponds, Colsa, Inc., February 1987.

F1.7.5.5 UK Ministry of Aviation - Explosives Research and Development Establishment Report No. 18/R/62, *Measurement of Human Capacitance and Resistance in Relation to Electrostatic Hazards with Primary Explosives*, 17 August 1962.

F1.7.5.6 NATO STANAG 4235, *Electrostatic Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces*.

F1.7.5.7 NATO STANAG 4239, *Electrostatic Discharge Testing of Munitions Containing Electroexplosive Devices*.

F1.7.5.8 NATO AOP 24, *Assessment and Testing of Munitions Containing Electroexplosive Devices to the Requirements of STANAG 4239.*

TABLE F1-1. Test Parameters.

Discharge Procedure	Voltage on C (kilovolts)	Capacitor C (picofarads)	Resistance R (ohms)	Discharge Inductance (microhenries)	Calibration Test Load (ohms)
Personnel	+25±5%	500±5%	5000±5%	< 5	1±5%
Personnel	-25±5%	500±5%	5000±5%	< 5	1±5%
Personnel	+25±5%	500±5%	500±5%	< 5	1±5%
Personnel	-25±5%	500±5%	500±5%	< 5	1±5%
Helicopter	+300±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-300±5%	1000±10%	1 max *	< 20	100±5%

- Total distributed discharge circuit resistance.

TABLE F1-2. Suggested Informational Test Parameters.

Discharge Procedure	Voltage on C (kilovolts)	Capacitor C (picofarads)	Resistance R (ohms)	Discharge Inductance (microhenries)	Calibration Test Load (ohms)
Personnel	+5±5%	500±5%	5000±5%	< 5	1±5%
Personnel	-5±5%	500±5%	5000±5%	< 5	1±5%
Personnel	+5±5%	500±5%	500±5%	< 5	1±5%
Personnel	-5±5%	500±5%	500±5%	< 5	1±5%
Personnel	+10±5%	500±5%	5000±5%	< 5	1±5%
Personnel	-10±5%	500±5%	5000±5%	< 5	1±5%
Personnel	+10±5%	500±5%	500±5%	< 5	1±5%
Personnel	-10±5%	500±5%	500±5%	< 5	1±5%
Personnel	+15±5%	500±5%	5000±5%	< 5	1±5%
Personnel	-15±5%	500±5%	5000±5%	< 5	1±5%
Personnel	+15±5%	500±5%	500±5%	< 5	1±5%
Personnel	-15±5%	500±5%	500±5%	< 5	1±5%
Personnel	+20±5%	500±5%	5000±5%	< 5	1±5%
Personnel	-20±5%	500±5%	5000±5%	< 5	1±5%
Personnel	+20±5%	500±5%	500±5%	< 5	1±5%
Personnel	-20±5%	500±5%	500±5%	< 5	1±5%
Helicopter	+25±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-25±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	+50±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-50±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	+100±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-100±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	+150±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-150±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	+200±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-200±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	+250±5%	1000±10%	1 max *	< 20	100±5%
Helicopter	-250±5%	1000±10%	1 max *	< 20	100±5%

* Total distributed discharge circuit resistance.

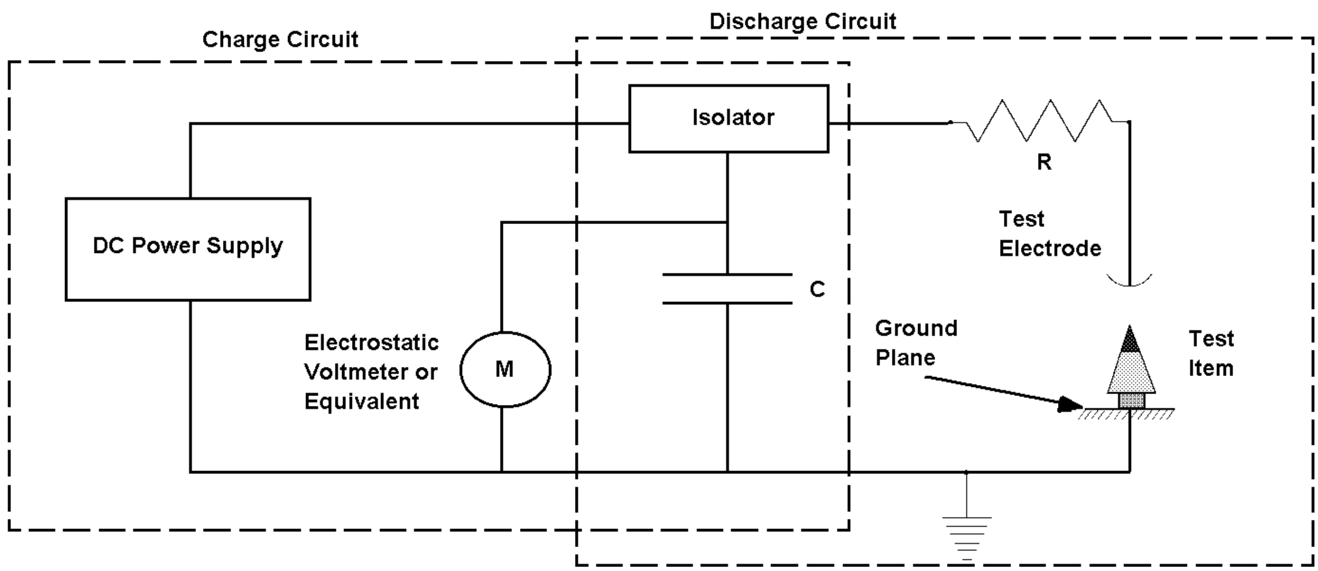

FIGURE F1-1. Functional electrical schematic for electrostatic discharge apparatus.

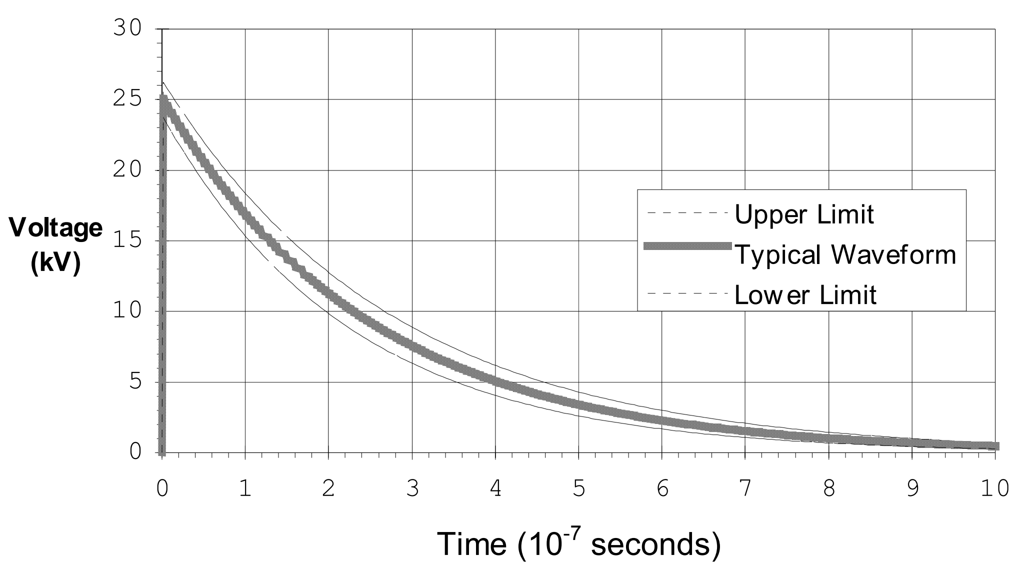

FIGURE F1-2. ESD waveform (500 ohm series resistance).

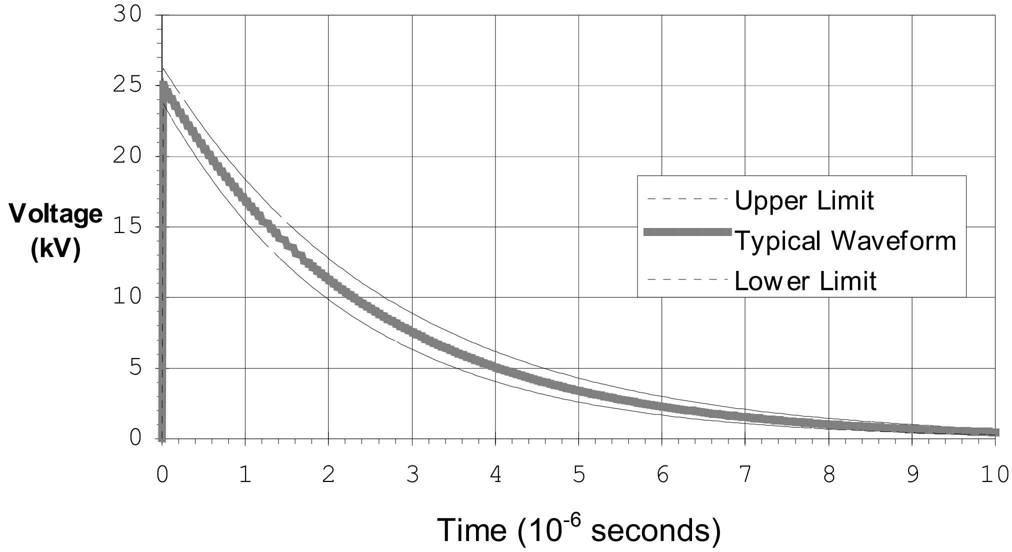

FIGURE F1-3. ESD waveform (5000 ohm series resistance).

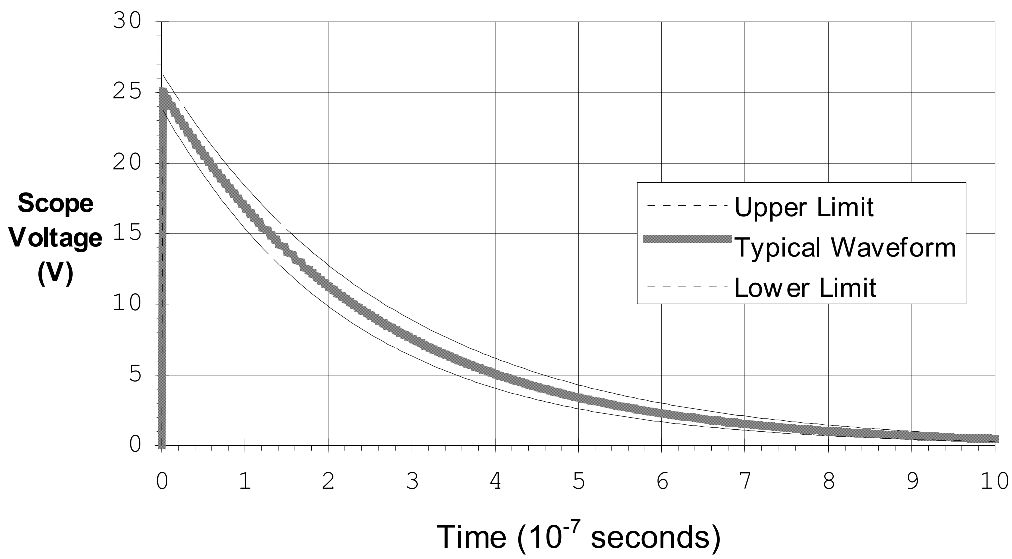

FIGURE F1-4. ESD waveform on oscilloscope (500 ohm series resistance).

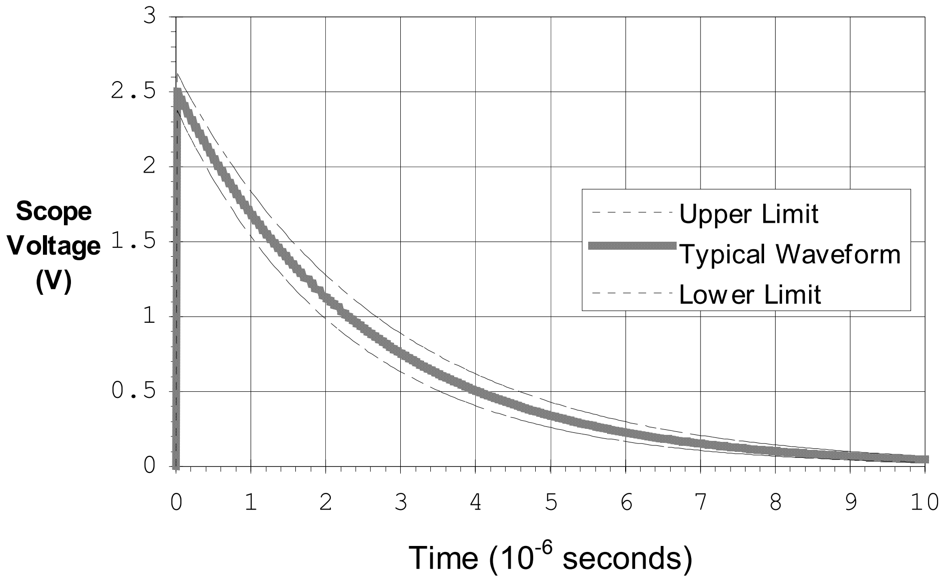

FIGURE F1-5. ESD waveform on oscilloscope (5000 ohm series resistance).

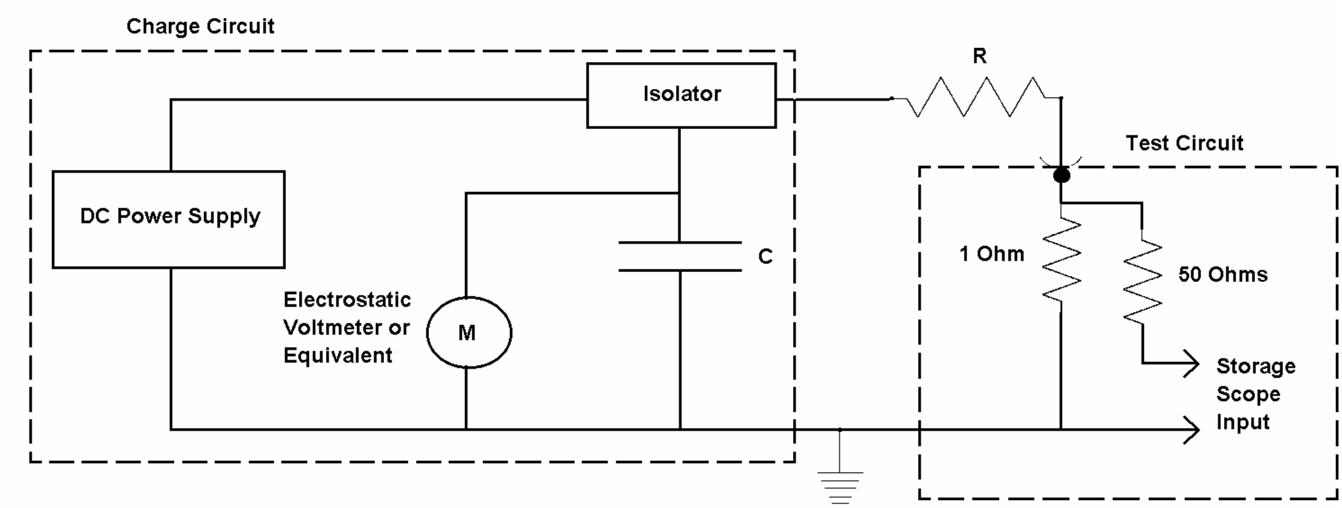

FIGURE F1-6. Personnel-borne ESD waveform calibration circuit.

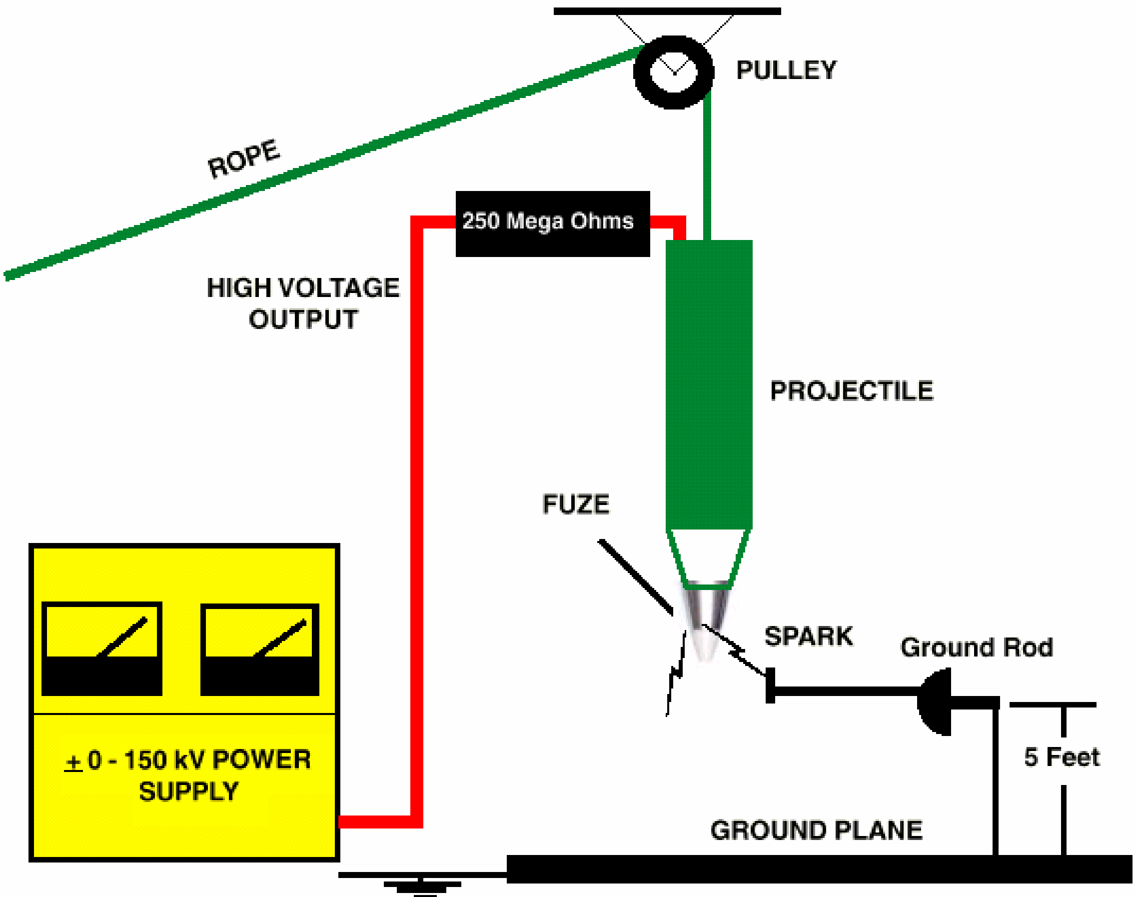

FIGURE F1-7. High Voltage Corona Set-Up.